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AN IMPLICATION DRAWN FROM TRAVEL TIME AND MILES OF TRAVEL

by Roger L. Creighton

This is an analysis of the trip length and trip time frequency distributions and their derivatives, travel time and miles of travel. Data furnished are for interval auto driver trips only. An implication is drawn of interest in the planning of road systems.

Trip time and trip length percentage frequency distribution are shown in Figure 1. Both are similar, except that the trip time frequency distribution is shifted more to the right. The reason for this is that short trips have slower speeds, as shown in Figure 2. Having slower speeds, these short trips tend to take longer, and this increases the frequency of the next interval of trip times, and so on. This process accounts for the shift to the right.

There is an unusual frequency of trips of 30 minutes' duration. This is likely to be an error of reporting -- since people are apt to round journey times to half an hour, rather than stipulate a more exact 25 or 35 minutes. For this reason the trip time frequency curve has been hand-fitted to the plots.

From the same data, the percentage distribution of travel distance by airline trip length and the percentage distribution of time in travel by duration of trips are plotted in Figure 3. The two curves differ. A higher percentage of total travel time is spent by trips of short duration than the percentage of total miles of travel by trips of short length. If speeds were uniform, the two curves would be identical. The difference reflects the slower speed of shorter trips.

What can be drawn from this information? It can be argued reasonably that the distribution of trip length over time is unlikely to change.[1] Therefore, the curve

[1] See Chapter VI of the forthcoming Volume II of the Study Report.

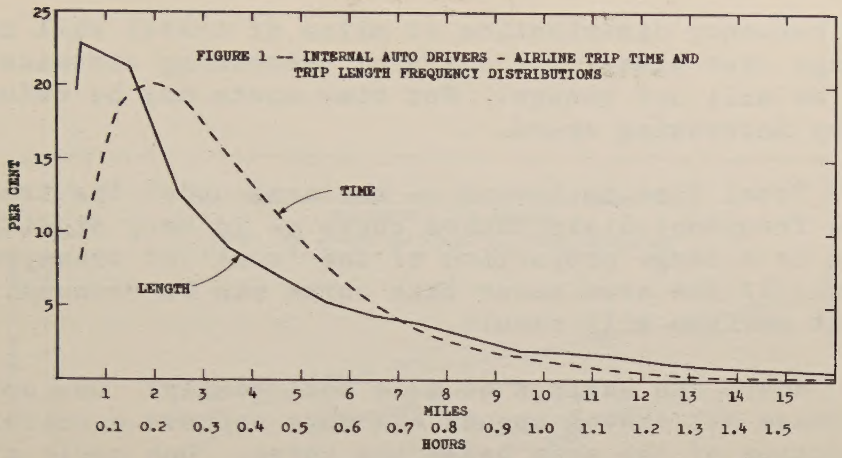
FIGURE 1 -- INTERNAL AUTO DRIVERS - AIRLINE TRIP TIME AND TRIP LENGTH FREQUENCY DISTRIBUTIONS
PER CENT
TIME
LENGTH
MILES
HOURS

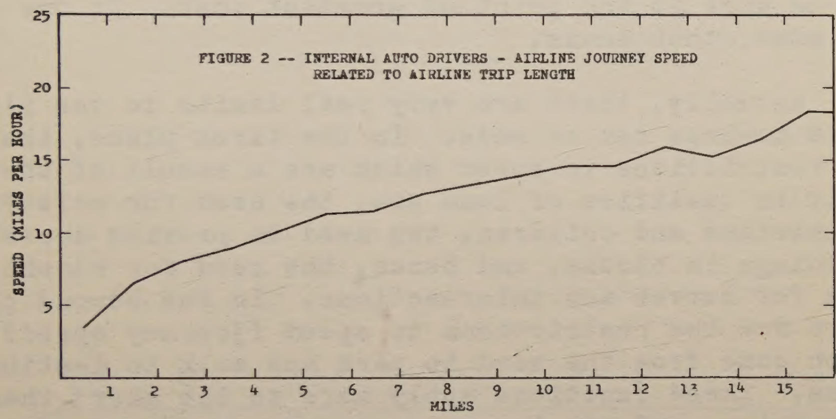
FIGURE 2 -- INTERNAL AUTO DRIVERS - AIRLINE JOURNEY SPEED RELATED TO AIRLINE TRIP LENGTH
SPEED (MILES PER HOUR)
MILES

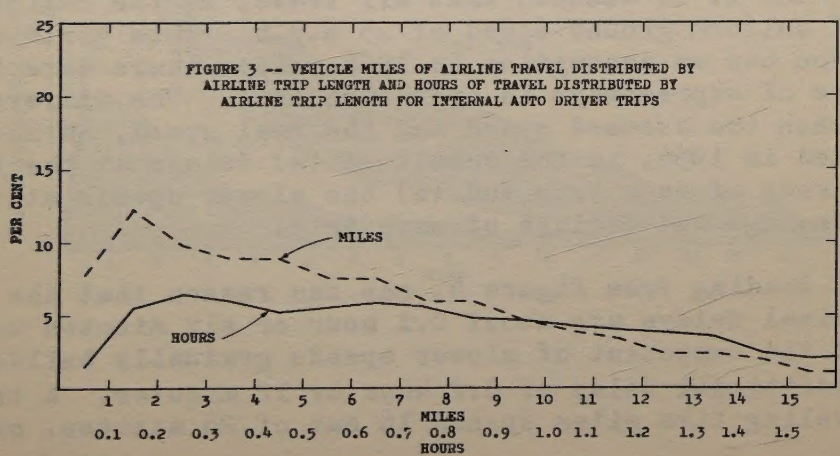
FIGURE 3 -- VEHICLE MILES OF AIRLINE TRAVEL DISTRIBUTED BY AIRLINE TRIP LENGTH AND HOURS OF TRAVEL DISTRIBUTED BY AIRLINE TRIP LENGTH FOR INTERNAL AUTO DRIVER TRIPS
PER CENT
MILES
HOURS
MILES
HOURS

of frequency distribution of miles of travel will not change over time. The costs of overcoming distance per se will not change. But time costs may be reduced, as by increasing speed.

Total time in travel -- the area under the travel time frequency distribution curve -- is very significant. This is a large proportion of the 'cost' of transportation. If the area under this curve can be reduced, then great savings will result.

Where can savings be made most easily? One could increase all travel speeds and thus achieve a uniform reduction of the area under the curve. One could attack the point of greatest time (trips of .0 - .4 hours or 0 - 24 minutes) on the theory that the greatest savings can be made at the point of greatest cost. Or one could use some other means.

Actually, there are very real limits to the places where savings can be made. In the first place, there are restrictions to speed which are a result of the built in qualities of land use, the need for safety for pedestrians and children, the need to provide access to buildings in blocks, and hence, the need for slowing down for curves and intersections. In the second place, there are the restrictions to speed (journey speed) which come from the need to park and walk to destinations. These functions apply more to the short than the long trips, and are the main reasons why Figure 2 takes its shape.

Let it be assumed that all travel in the region is at a uniform ground speed of 25 m.p.h. This would not be too bad an assumption in 1956, since there were few miles of expressways in operation then. The difference between the assumed speed and the real speed, as reported in 1956, is the result of (a) delays at the terminal ends of each trip and (b) the slower speeds at the beginnings and endings of each trip.

Reading from Figure 4, one can reason that the terminal delays are about 0.1 hour or six minutes and that the component of slower speeds gradually builds up an additional delay of 0.2 hour or 12 minutes. A trip traveling five miles spends 16 out of 28 minutes, or

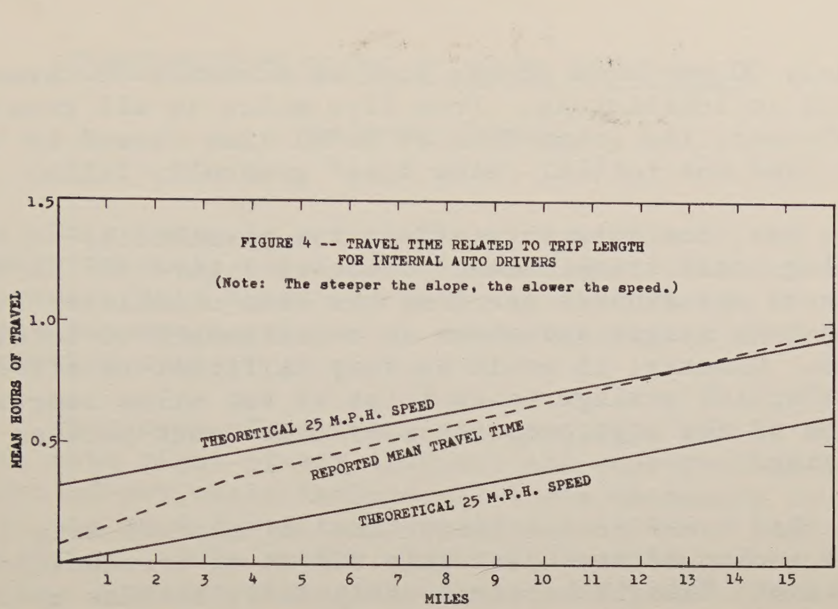
FIGURE 4 -- TRAVEL TIME RELATED TO TRIP LENGTH
FOR INTERNAL AUTO DRIVERS
(Note: The steeper the slope, the slower the speed.)
MEAN HOURS OF TRAVEL
1.5
1.0
0.5
THEORETICAL 25 M.P.H. SPEED
REPORTED MEAN TRAVEL TIME
THEORETICAL 25 M.P.H. SPEED
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
MILES

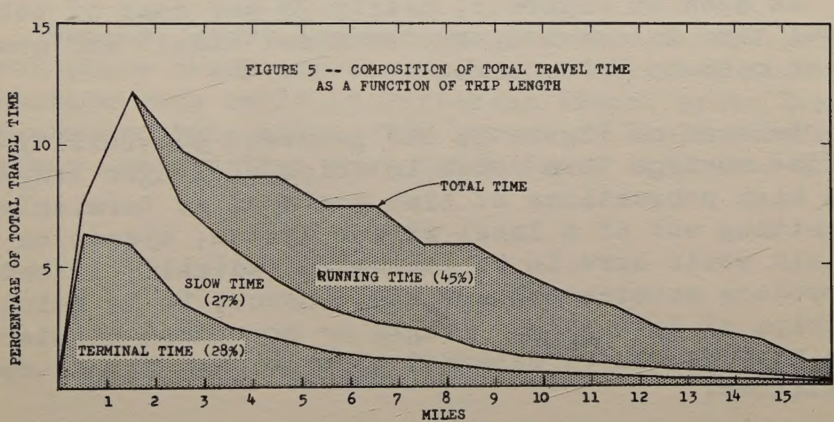
FIGURE 5 -- COMPOSITION OF TOTAL TRAVEL TIME
AS A FUNCTION OF TRIP LENGTH
PERCENTAGE OF TOTAL TRAVEL TIME
15
10
5
TOTAL TIME
RUNNING TIME (45%)
SLOW TIME
(27%)
TERMINAL TIME (28%)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
MILES

nearly 60 per cent of its time as a result of these two built in inhibitions. From five miles to all greater distances, the proportion of total time caused by terminal time and initial 'slow time' gradually falls.

Now, how does this affect the possibility of reducing total travel time? Consider Figure 5. Terminal time of six minutes per trip has been calculated for each trip length and shown in relationship to total time. Clearly, it would be very difficult to affect substantial savings below trips of two miles length because of the high proportion of time spent parking and walking.

Now consider the 'slow time' of shorter trip lengths. What amount of time does this add as an irreducible minimum? This is harder to stipulate, because speeds can be improved on arterial and local streets and this would effectuate some time savings. As a minimum, let us say that it is the difference in time between traveling at 25 m.p.h. (the assumed desired speed) and 10 m.p.h. for a distance of two miles. This time is 0.12 hours, or seven minutes. Let us say that this time loss cannot be saved due to the structuring of local streets and safety. Actually, this is conservative, since the data indicate this time is nearly 0.2 hours or 12 minutes.

As seen on Figure 5, nearly 28 per cent of total travel time is eaten up by 'terminal time,' and nearly 27 per cent by 'slow time.'

As seen on Figure 5, the greatest possibility of time savings then comes in trips of longer length. When high proportions of time are used at terminals and in getting out of a local street system, speeds on arterials would have to be increased radically in order to produce substantial savings. Hence, it is mainly in trips of five miles' length or more that substantial time savings can be obtained by providing higher speed facilities.

CONSTRUCTION COSTS OF URBAN EXPRESSWAYS

by Hyman Joseph

This paper is a preliminary analysis of the construction costs only (not right-of-way costs) of expressways that have been built in the Chicago area. Equations are developed to estimate roughly future construction costs.

The costs of building an expressway can be broken down into right-of-way (r.o.w.) and construction costs. Right-of-way costs include all costs necessary to prepare the land for actual construction, i.e., land acquisition, title search, legal and building demolition costs. Construction costs consist of those costs incurred for the actual construction of the expressway, i.e., bridges, grading, paving and drainage costs.

Construction costs[1] of Congress Street, Edens and Calumet-Kingery Expressways were broken down by CATS ring. (CATS rings radiate outward from the Central Business District.) The data was further differentiated as to bridges and other construction. Bridges consisted of all expressway separations. Such separations are due to crossroads, railroad tracks, rivers, railyards and similar items.

Because there has been an increase in the price level since these expressways were built and the expressways were built at different times, price level adjustments were made. The Bureau of Public Roads' highway construction cost index for a composite standard

[1]The basic data was obtained from the Expressway Section of the Illinois Highway Department. The data is titled 'Status of Expenditures on Chicago Metropolitan Expressway System, Ending - December 31, 1958, Chicago - Cook County - State.'

mile[2] was used to obtain price level factors for each year. Each cost item was multiplied by the appropriate price level factor to bring all construction costs to the 1958 price level.

Table 1 gives the construction costs per mile, by ring, for the Congress Street, Edens and Calumet-Kingery Expressways, both with and without price level adjustments. The range of total costs is from 14.14 million dollars per mile in Ring 1 of Congress Street to 1.34 million dollars per mile in Ring 7 of Edens. For each expressway, the total construction costs per mile decrease with each higher numbered ring (rings are numbered from 0, the CBD, to 7 in the outlying Study areas). For a complete expressway system, the costs per mile would be somewhat higher because of more expressway-to-expressway interchanges.

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[2] The index numbers were obtained from the United States Department of Commerce, Office of Business Economics.

TABLE 1 -- Expressway Construction Costs Per Mile
(In Millions of Dollars)

	With Price Level Adjustments			Without Price Level Adjustments		
	Bridges	Other	Total	Bridges	Other	Total
Congress Street Expressway						
Ring 1	7.98	6.16	14.14	7.30	5.70	13.00
2	3.40	4.84	8.24	3.27	4.47	7.74
3	2.13	4.13	6.26	2.03	3.85	5.88
5	1.26	3.25	4.51	1.19	3.05	4.24
Edens Expressway						
Ring 5	.71	1.03	1.74	.60	.89	1.49
6	.52	.94	1.46	.45	.80	1.25
7	.25	1.09	1.34	.21	.92	1.13
Calumet-Kingery Expressways						
Ring 6	1.54	1.00	2.54	1.31	.88	2.18
7	.53	.90	1.43	.46	.80	1.26

In Table 2, total construction costs per mile (price adjusted) for the expressway segments are compared with the net residential density of the districts in which the segments are located and their average distance from the CBD. These numbers are plotted in Figures 1 and 2, so that their relationship may be better seen.

Figure 1 compares total construction costs per mile on the Y-axis with net residential density[3] on the X-axis. A regression line computed with the data is: $Y = .999 + .0708\ X$. There is a discrepancy between the costs in Ring 5 for Congress Street and Edens. Part of this discrepancy will subsequently be explained by an analysis of bridges.

[3]Gross density was considered, but did not correlate well with construction costs.

TABLE 2 -- Net Residential Density and Average Distance From CBD Related to Expressway Segments

	Total Construction Costs Per Mile (In Millions Of Dollars)	Net Residential Density (Thousands of Persons Per Square Mile)	Average Distance From Central Business District (In Miles)
Congress Street Expressway			
Ring 1	14.14	184.70	1.37
2	8.24	107.52	3.41
3	6.26	68.23	5.45
5	4.51	17.97	11.41
Edens Expressway			
Ring 5	1.74	19.46	11.41
6	1.46	9.02	15.68
7	1.34	10.24	23.36
Calumet-Kingery Expressways			
Ring 6	2.54	29.89	15.68
7	1.43	14.72	23.36

FIGURE 1

TOTAL CONSTRUCTION COSTS PER MILE VERSUS NET RESIDENTIAL DENSITY

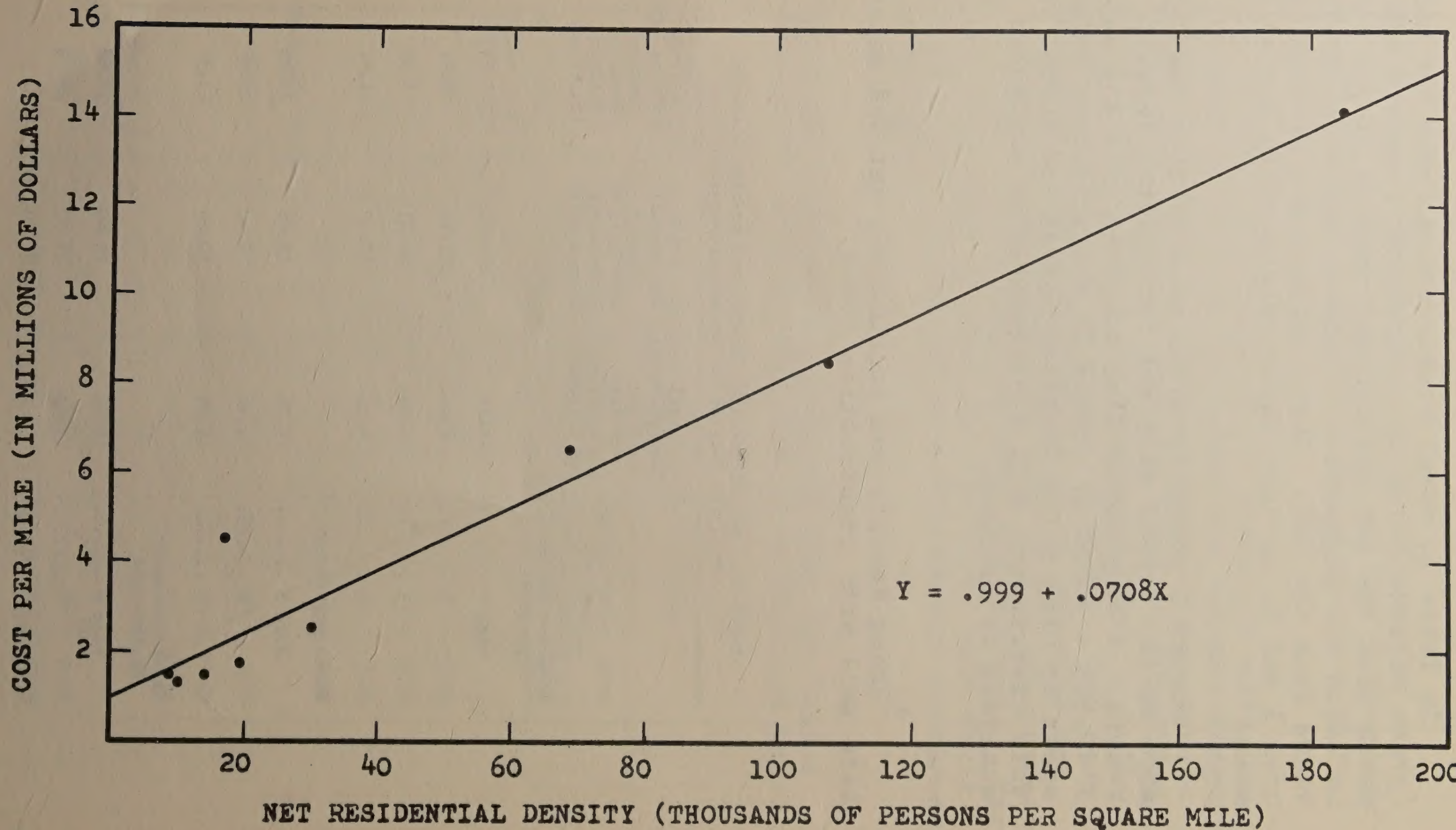


Figure 2 compares total construction costs per mile on the Y-axis with distance from the CBD on the X-axis. Note that the Y-axis is logarithmic. A regression line computed with the data is: $\log Y = 1.0435 - 0.04303 X$. Again, there is a discrepancy between costs in Ring 6 for Edens and Calumet Expressways which will subsequently be explained by an analysis of their bridges.

Which of the two computed equations is the better predictor of future expressway costs? Denser residential land implies greater construction costs because of higher cost of relocating utilities, difficulty of moving materials to construction sites, more expressway ramps to facilitate exit and entrance, more pedestrian overpasses, more extensive drainage requirements, and more bridges. Distance from the CBD would remain stable over time and would not reflect changes in residential land use and, therefore, construction costs. Net residential density would appear to be a better predictor of future construction costs than would distance.

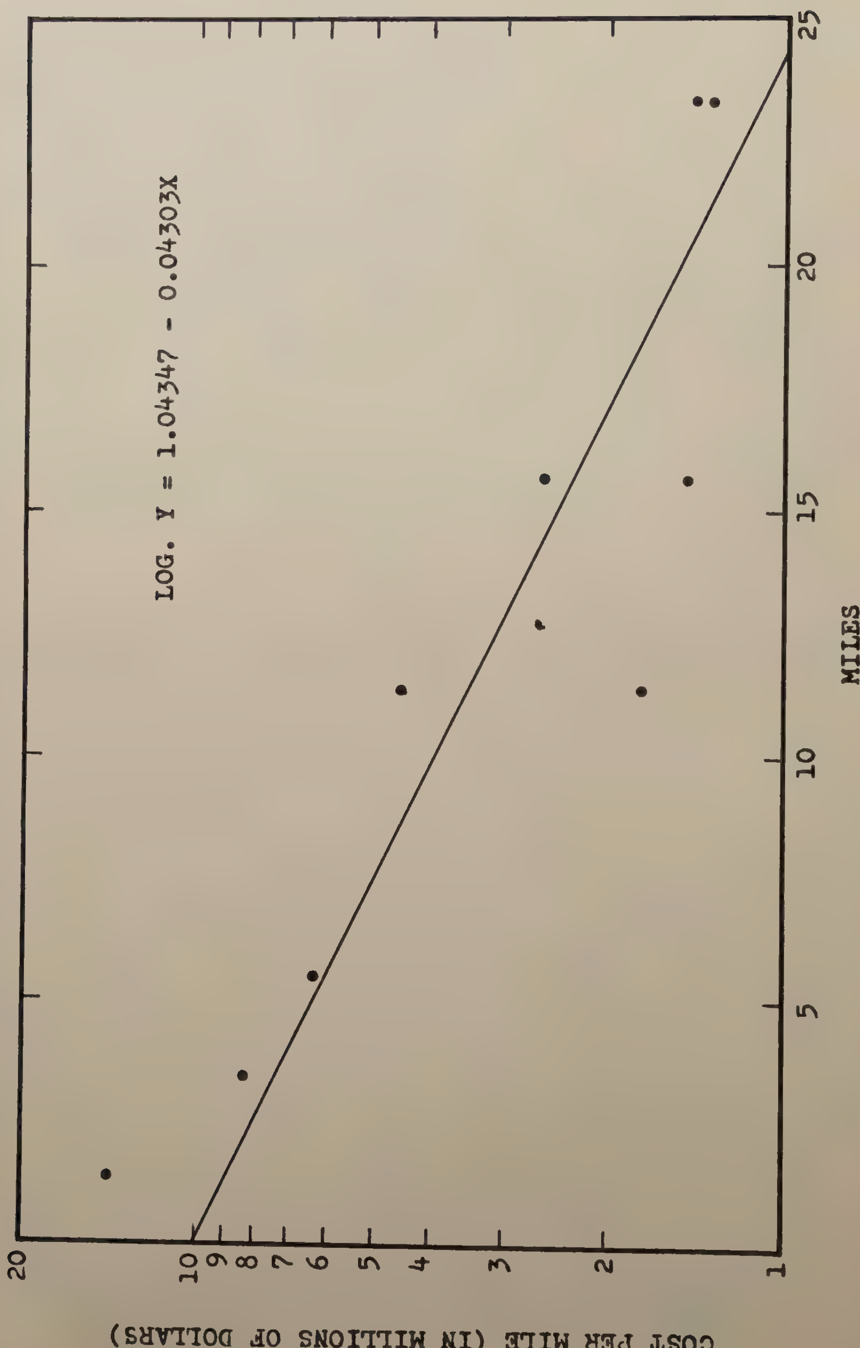
Table 3 gives the number of bridges per mile and the cost per bridge for each expressway segment. In Ring 6, Calumet Expressway has more than twice as many

TABLE 3 -- Analysis Of Bridge Frequency And Cost

	Bridges/Mile	Cost/Bridge (Price Adjusted In Millions Of Dollars)
Congress Street Expressway		
Ring 1	5.50	1.45
2	4.50	.76
3	3.33	.64
5	3.60	.35
Edens Expressway		
Ring 5	2.16	.33
6	1.45	.36
7	.56	.45
Calumet-Kingery Expressways		
Ring 6	3.04	.51
7	1.49	.36

FIGURE 2

TOTAL CONSTRUCTION COSTS PER MILE VERSUS DISTANCE FROM THE C.B.D.



bridges per mile than has Edens, and the cost per bridge for Calumet is higher. This explains the cost discrepancy between these segments which was noted earlier. In Ring 5 Congress Street has 67 per cent more bridges than has Edens. This explains only a portion of the differences in total construction costs between them.

The other construction costs per mile for Congress Street in Ring 5, as shown in Table 1, are more than triple the other construction costs per mile for Edens in that ring. Part of the difference in other construction costs can be explained by the great number of ramps on Congress Street -- more than twice the number of ramps per mile on Edens. The large number of ramps in Ring 5 of Congress enables short trips to use the facility, but increases construction costs.

All of the expressway segments considered in this paper do not have the same number of lanes. Table 4 shows what their costs would be if they each had four lanes in each direction. Since Congress in Rings 1, 2, and 3 has four lanes, its costs in Table 4 are identical

TABLE 4 -- Expressway Costs Per Mile With Lane Standardization
(Four Lanes Each Direction)

	Price Adjusted		
	Bridges	Other	Total
Congress Street Expressway			
Ring 1	7.98	6.16	14.14
2	3.40	4.84	8.24
3	2.13	4.13	6.26
5	1.26	4.33	5.59
Edens Expressway			
Ring 5	.71	1.37	2.08
6	.52	1.25	1.77
7	.25	1.45	1.70
Calumet-Kingery Expressways			
Ring 6	1.54	1.67	3.21
7	.53	1.80	2.33

to the costs shown in Table 1. Bridge costs for all segments are assumed to be the same regardless of the number of lanes, while other construction costs are assumed to be proportional to the number of lanes. The adjustments would tend to understate bridge costs and overstate other costs, since bridge costs do go up somewhat when the number of lanes is increased and the increase in other construction costs is less than proportional to the number of lanes. Figure 3 plots these adjusted total costs against NRD, and a line is hand-fitted to the points (Congress Street in Ring 5 was not considered when the line was hand-fitted). The linear relationship between construction costs and NRD can be seen to hold even if the number of lanes is standardized.

Conclusion.

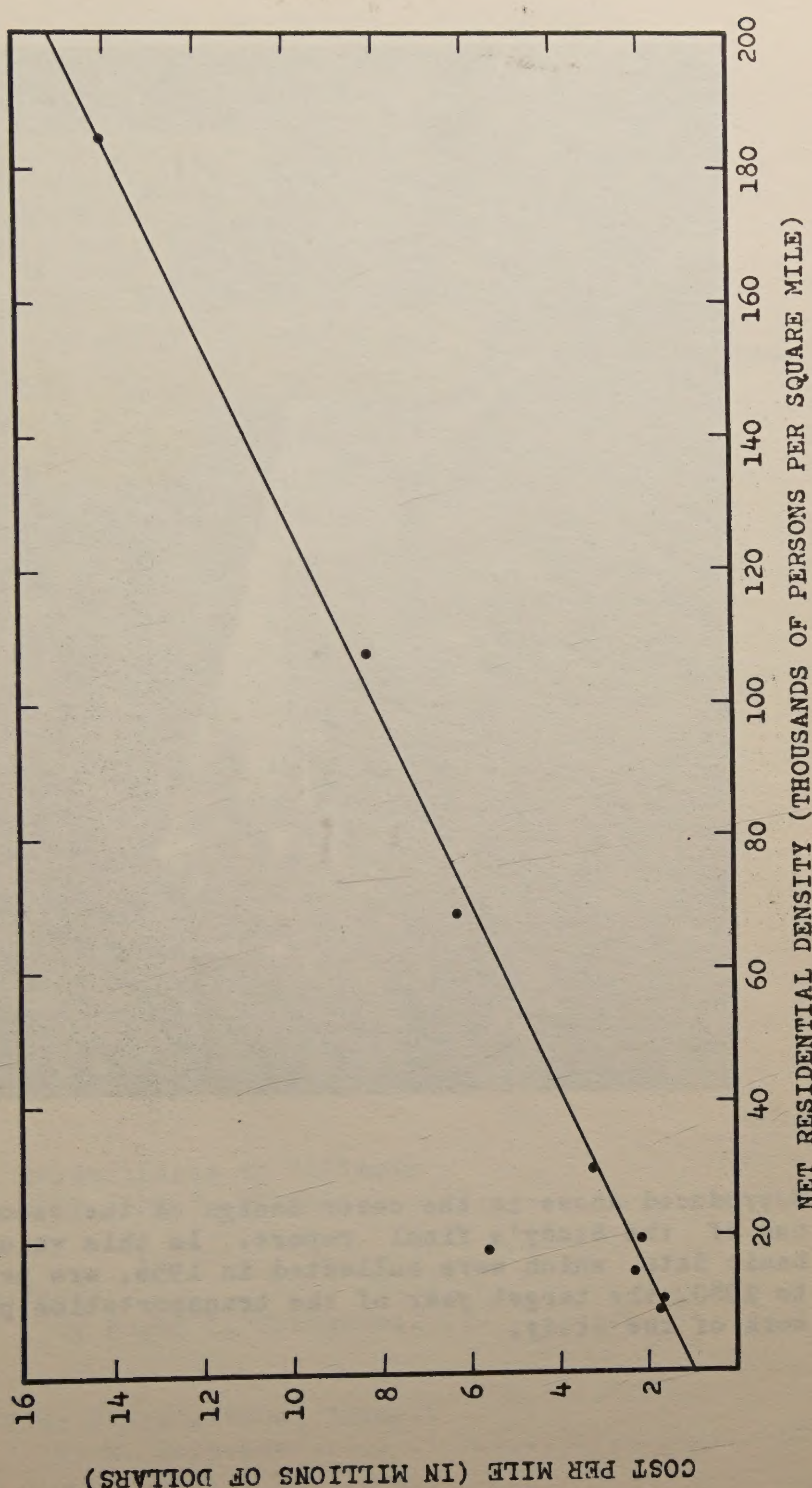
Construction costs of expressways that have been built may be used to predict future construction costs by relating costs to net residential density. There appears to be a linear relationship between total construction costs per mile and net residential density. NRD appears to be an index of the costs of utility relocations, material movements, drainage requirements, bridges, pedestrian overpasses and ramps. A regression line was computed with the equation:

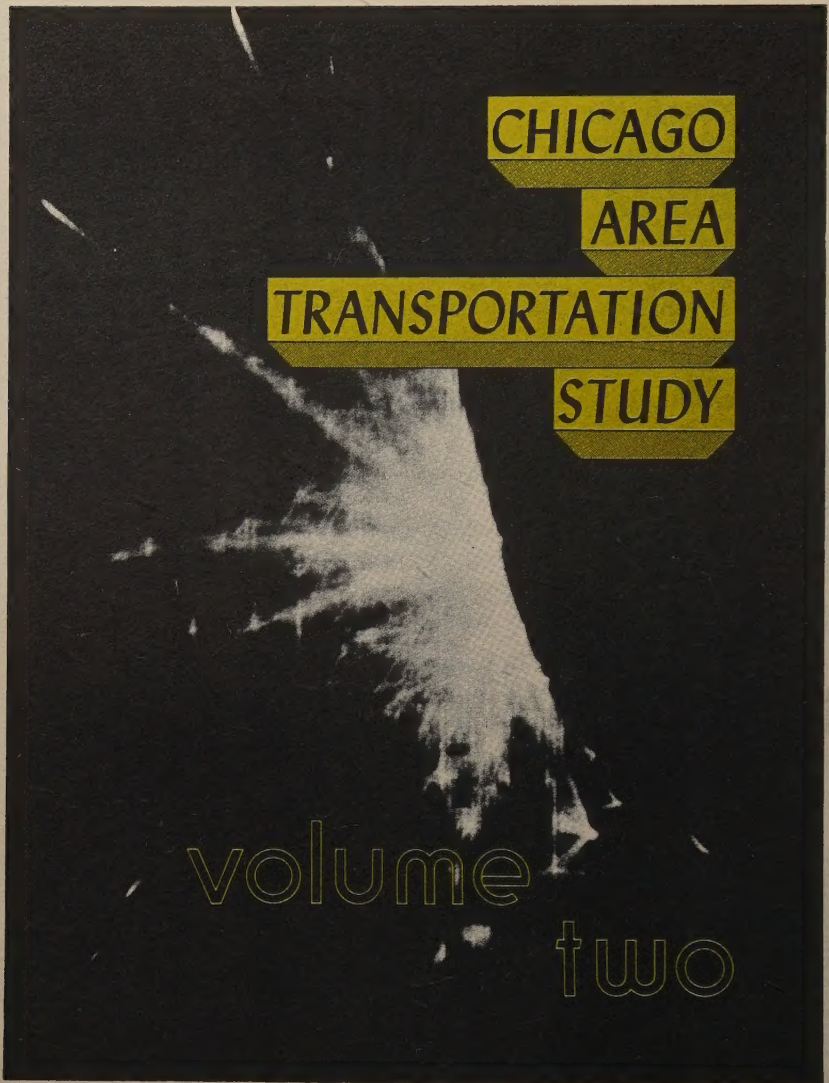
$$Y = 0.999 + 0.0708\ X$$

where Y is total construction costs per mile in millions of dollars and X is NRD in thousands of persons per square mile. When net residential density (X) is zero, construction costs of approximately $1,000,000 are predicted by the equation.

FIGURE 3

TOTAL CONSTRUCTION COSTS PER MILE (ADJUSTED FOR LANES)
VERSUS NET RESIDENTIAL DENSITY





Reproduced above is the cover design of the second volume of the Study's final report. In this volume, the basic data which were collected in 1956, are projected to 1980, the target year of the transportation planning work of the Study.